THE LIGHT SOURCE PROBLEM: THE EFFECT OF HETEROGENEOUS STELLAR PHOTOSPHERES ON SEARCHES FOR TRANSITING EXOPLANET BIOSIGNATURES. B. V. Rackham[1], D. Apai[2]. M. S. Giampapa[3]. [1]Dept. of Astronomy, University of Arizona, 933 North Cherry Ave., Tucson, AZ 85721, USA (brackham@as.arizona.edu); [2]University of Arizona, Tucson, AZ. [3]National Solar Observatory, Tucson, AZ.

Introduction: Transmission spectroscopy offers the exciting possibility of studying terrestrial exoplanet atmospheres in the near-term future. Ground- and space-based facilities in the coming decade may identify biologically produced molecules from opportune targets with this technique [1, 2, 3], which can constrain the chemical composition of the upper atmosphere of a transiting exoplanet. The Transiting Exoplanet Survey Satellite (TESS), scheduled for launch next year, is expected to discover thousands of transiting exoplanets around bright host stars, including an estimated 48 habitable zone exoplanets with radii less than two Earth radii [4]. The brightness of the TESS host stars, combined with refined observational strategies and near-future facilities, will enable searches for atmospheric signatures from smaller and cooler exoplanets.

These observations, however, will be increasingly subject to noise introduced by heterogeneities in the host star photospheres, such as star spots and faculae. In short, the transmission spectroscopy method relies on the assumption that the spectrum of the transit chord does not differ from that of the integrated stellar disk or, if it does, the contribution of photospheric heterogeneities to the transmission spectrum can be constrained by variability monitoring. However, any axisymmetric populations of spots and faculae will strongly affect transmission spectra, and their presence cannot be deduced from monitoring efforts. Given this, a clear need exists for a more robust understanding of stellar contamination on transmission spectra.

In a recent study on the transiting sub-Neptune GJ 1214b, for example, we found its optical transmission spectrum is strongly influenced by unocculted stellar faculae in the photosphere of the host star [5]. Follow-up work utilizing our same modeling framework for assessing the stellar and exoplanetary contributions to transmission spectra shows that a large subset of published spectra are likewise affected by heterogeneous stellar photospheres, leading to misinterpretations of spectral feautres purportedly originating in the exoplanets' atmospheres [6]. In order to successfully identify and interpret biosignatures, the community will need to develop metrics for understanding when heterogeneous stellar photospheres will be important and methods for handling their effects.

This Work: Here we summarize our work [7] on the impact of heterogeneous stellar photospheres on transmission spectra and detail implications for atmospheric characterization efforts. We focus on M dwarf exoplanet host stars, which offer the best opportunities for atmospheric characterization of small, rocky exoplanets in the near-term future.

By modeling spot and faculae distributions in stellar photospheres, we find that spot-covering fractions extrapolated from observed variability amplitudes are significantly underestimated. Likewise, corrections to transmission spectra based on variability monitoring likely fall short of the actual stellar spectral contamination. We provide contamination spectra across a range of spectral types for typical levels of stellar activity, including contributions from spots and faculae. For M dwarfs, molecular absorption features in spots can imprint apparent features in transmission spectra on the scale of atmospheric features from small exoplanets, while contamination from unocculted faculae can mask real exoplanetary features. Additionally, we explore the specific case of the TRAPPIST-1 system, determining realistic ranges of spot- and faculae-covering fractions consistant with the observed variability amplitude and providing the associated stellar contamination spectra.

Our results suggest that constraining stellar contamination will likely be a limiting factor for detecting atmospheric features in transmission spectra of low-mass exoplanets around late-type stars from TESS, including potential biosignatures from habitable zone exoplanets.

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